ANCOVA results for primary outcomes of cartilage volumes (mm3) and average symptoms pain (KOOS)

	Baseline		Follow-up		Change (Follow-up - Baseline)		Difference†	
	Unloaders Mean (SD)	Loaders Mean (SD)	Unloaders Mean (SD)	Loaders Mean (SD)	Unloaders Mean (SE)	Loaders Mean (SE)	Mean Difference (95% CI)	P
Cartilage volume	2,603(734)	2,554 (454)	2,269(72.5)	2,315(86.3)	-316 (72.5)	-270(86.3)	-46.3(-241.3;148.8)	0.64
Average symptoms	66.6 (16.4)	64.3(17.1)	63.4 (1.6)	64.2(1.9)	-2.4(1.6)	-1.6(1.9)	-0.8(-5.1;3.6)	0.73

†Adjusted for baseline value age, gender, BMI and other potential confounding factors.

(excluding sports and recreation subscale) over 52 weeks. Changes from baseline to 1 year were compared between groups using analysis of covariance adjusting for baseline values, age, gender, BMI and other potential confounding factors.

Results: 157 participants (82% of the CAROT cohort) were included in the biomechanics sub-cohort. Of these 100 were classified as Unloaders and 57 as Loaders based on gait changes from baseline to after the weight loss: The Unloaders on average reduced the peak knee compression force during walking by -509N (18%) and the Loaders increased the peak compression force by 425N (19%). There were no baseline differences between the groups except that the Loaders walked with significantly higher (11%) knee loads. Both groups showed the same significant reduction in cartilage volume and symptoms at one year yet there were no statistically significant difference in the change in tibiofemoral cartilage volumes or average symptoms (table) between Loaders and Unloaders.

Conclusions: For obese patients undergoing a significant weight loss, increased knee joint loading (Loaders) for 1 year did not accelerate disease progression (as assessed by changes in tibiofemoral cartilage volume and worsening of symptoms) relative to a similar weight loss group (Unloaders) that had reduced ambulatory knee joint loads.

This is the first study to assess consequences of increased knee joint loading on OA progression and the results support the application of interventions that improve function and potentially increase ambulatory load in obese subjects since there does not appear to be detrimental effects of increased load in this group.

Trial registration: {NCT00655941}

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QUADRICEPS POWER USAGE DURING GAIT IS RELATED TO MAXIMAL ISOKINETIC POWER CAPACITY IN PATIENTS AFTER TOTAL KNEE ARTHROPLASTY

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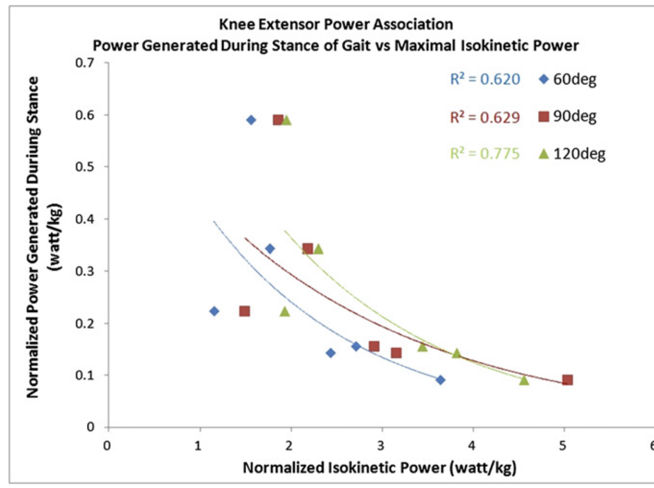
Quadriceps weakness is common in individuals with knee osteoarthritis and is exacerbated in the early period after total knee arthroplasty (TKA). Weakness contributes to the lower extremity functional deficits. To further examine the influence of quadriceps weakness on performance of functional tasks, we examined how the capacity to develop force by the quadriceps (maximal muscle power) is associated with the use of quadriceps muscle group during a functional task. **Purpose.** The aim of this study was to examine the associations between the peak knee extensor power generated with the surgical limb during the stance phase of gait and maximal power generated with the same limb during isokinetic testing.

Methods. Six subjects (men= 4; women= 2), 6 mos after TKA, were assessed using motion analysis to determine the peak knee extensor power generated during the stance phase of gait. Subjects also completed maximal voluntary isokinetic knee extension contractions at three velocities (60, 90, 120 deg/s). Regression analyses were used to assess the association between the peak knee extensor power generated during the stance phase of gait and the peak knee extensor power (joint torque X angular velocity) acquired during isokinetic testing.

Results. The peak knee extensor power generated during the stance phase of gait was best fit using an exponential regression with the peak knee extensor power produced during isokinetic testing (60 deg/s R2= 0.620; 90 deg/s= 0.629; 120deg/s= 0.775).



The average angular velocity of the knee joint at the moment of peak power generation was 38.7 ± 15.2 deg/s, which occurred during the stance phase of gait near peak knee flexion.

Conclusions. The peak knee extensor power produced during the stance phase of gait was associated with the maximal power produced during isokinetic contractions at all three velocities tested, even though the velocities achieved during the two tasks were different. The findings here are clinically relevant because, motion analysis is not readily available or cost effective for functional assessments of individuals with knee osteoarthritis or patients after TKA; however, power production during isokinetic testing is more practical and can provide additional insight into how patients utilize their quadriceps during gait.

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DEVELOPMENT OF A MATERIALS-TESTING FIXTURE TO ENABLE ASYMMETRIC LOADING OF THE LOWER LIMB: AN APPLICATION OF *IN-VIVO* GAIT DATA

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Purpose: Experimental parameters to test material properties of fixation plates used for medial opening wedge high tibial osteotomy (HTO) are typically based on static, radiographic measures of bony alignment and rarely consider *in-vivo* gait data. During walking, the ground reaction force (GRF) passes medial to the stance limb, creating a frontal plane lever arm, an adduction moment, and subsequent asymmetric loading. The purpose of this study was to design and test a novel multi-axis fixture to be used in a materials testing machine to enable asymmetric loading of the lower limb in a manner more representative of human gait. Four hypotheses were tested: (1) distribution of load on the medial side would range considerably depending on experimental parameters; (2) at a representative frontal plane lever arm of 3cm, distribution of load on the medial side would be approximately 60-75%; (3) coefficients of variation (CoV) for load distribution measurements obtained within a single testing session (repeatability) would be ≤2%; and (4) CoV for measurements obtained from separate testing sessions completed within and between test days (reproducibility) would be $\leq$ 5%.

Methods: Three-dimensional kinematics and kinetics collected from 166 patients with medial compartment knee osteoarthritis before and after high tibial osteotomy were used to identify representative values for the frontal plane lever arm about the tibiofemoral joint, ground reaction force, and tibiofemoral angles. A fixture was designed and fabricated based on these data and used in a materials testing machine with a pressure measurement system to quantify the distribution of applied loads between medial and lateral contact surfaces of proximal tibia and distal femur sawbones.

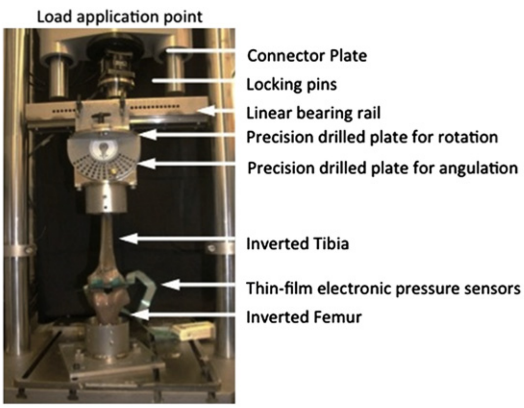

Figure 1. Photograph of inverted tibia and femur sawbones mounted in the fixture designed to position and load the lower limb based on 3D gait kinematic and kinetic gait data. A stainless steel plate connected the multi-axis fixture to the actuator of the materials testing machine. With reference to the anatomical planes of motion, the capability to translate the fixture horizontally along a linear bearing rail in 1 cm increments (+/-10 cm) mimicked the frontal plane level arm about the tibiofemoral joint. A precision-drilled stainless steel plate with a series of holes provided the capability to rotate the inverted tibia to alter varus/valgus angulation in half-degree increments (+/- 35 degrees). A second plate enabled internal/external rotation in 5-degree increments (+/- 15 degrees). The tibia and femur were potted and aligned to create 15 degrees of flexion. All positions were held with locking pins and bolts. Pressure distribution between medial and lateral contact surfaces of the proximal tibia and distal femur was measured with thin-film electronic pressure sensors while a load of 900 N was applied by the materials testing machine.

First, the change in distribution of medial-lateral compartment loads was evaluated using three lever arms, the corresponding angles between the tibia and GRF, and a compressive force of 900N (the approximate mean frontal plane GRF from the *in vivo* gait data). Then, reliability of load distribution was tested by repeating measurements using a 3cm lever arm (the mean frontal plane lever arm from the in vivo data 24 months post-surgery).

Results: The change in distribution of loads using lever arms of 1, 3 and 5cm, ranged from approximately 40-to-85%. The load on the medial side was 70.1%, when using a representative lever arm of 3cm. Coefficients of variation for repeated measures ranged from 0.66%-to-1.83% for trials within one test session, was 2.70% for trials between test sessions within one day, and was 4.88% for trials between days.

Conclusions: Results demonstrate appropriate asymmetric loading and excellent test-retest reliability. These findings suggest the fixture enables loading of the lower limb in a manner more representative of walking and will be used for future materials testing of HTO plate designs.

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INERTIAL SENSOR BASED GAIT ANALYSIS: A CLINICAL APPLICATION IN PATIENTS WITH OSTEOARTHRITIS

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Purpose: Commonly used patient reported outcome scores demonstrate poor/moderate correlations with objective performance-based measures such as gait analysis. Recent advances in miniaturization and cost of ambulatory motion sensors has made accelerometer based gait analysis (AGA) suitable for clinical research. The use of gyroscopes in conjunction with accelerometers (i.e. inertial sensors), enables the assessment of position and angular movements of body segments and provides ambulatory kinematic characterization of gait. We investigated commonly used gait parameters and whether they correlate with patient reported and surgeon reported outcome scores.

Methods: Gait was studied in healthy subjects (n=20), in patients with end stage hip OA (n=20) and in patients with end stage knee OA (n=20). Subjects walked 20 meters in an indoor environment along a straight flat corridor at their own preferred speed. A 3D inertial sensor was positioned centrally between the posterior superior iliac spines (PSIS) overlying S1.

Results: Comparing gait parameters of end stage hip OA patients with an age and gender matched healthy control group, significantly lower walking speed, longer step duration and shorter step length was observed. There was a significant difference in walking time between end stage hip OA patients (seconds 18.7 +/- 3.8) and healthy subjects (15.6 +/- 1.7) ($p<0.05$) and end stage knee OA patients (21.2 seconds =/- 4.7) ($p<0.05$) and healthy subjects. There was no significant difference between the walking time between hip and knee OA patients. However, after correcting for walking speed between groups, significantly less average range of motion of Pelvic Obliquity (RoMpo) was observed for patients with end stage hip OA (5.5 +/-1.4) compared to healthy subjects (6.7 +/- 1.9) and patients with end stage knee OA (7.03 +/- 1.9).

Patients with end stage hip OA in this study demonstrated a mean Harris Hip Score (HHS) of 66.7 $\pm$15.7. Pearson's correlation coefficients between HHS and gait parameters ranged from 0.18 to 0.40. Hip OA patients showed a mean WOMAC Hip score of 58.9 $\pm$19.2. Patients with end stage knee OA showed a mean WOMAC Knee score of 51.5 $\pm$12.4. WOMAC scores in knee OA patients were moderately-well correlated to speed, cadence and step time: r= 0.53; 0.51; -0.48; respectively ($p<0.05$). Furthermore, knee OA patients demonstrated a mean American Knee Society Score (AKSS) of 51.9 $\pm$11.5 with no correlations to gait parameters.

Conclusions: Gait parameters were different between those with end stage OA of either the knee or hip from healthy subjects. The Pelvic obliquity range of motion was significantly decreased in patients with Hip OA while timed parameters did not differentiate between the groups.

AGA detects disease dependent functional limitations which can be used for longitudinal follow-up. As gait parameters only moderately correlated with classic outcome scores, AGA may measure another dimension of physical function and could be used measure recovery of OA patients before and after joint replacement.

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COMPARISON OF IN VIVO KINEMATICS OF THE KNEE BETWEEN GAIT AND SQUAT

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Purpose: Gait kinematics provide important information to understand the load on the articular surface because gait is the most common activity in daily life, and produces a cyclically reproducible pattern of loading.

While a number of studies investigated the knee kinematics during squat which shows medial pivot pattern, kinematics during gait is not well studied, nor compared with that during squat.

The purpose of this study was to compare in vivo kinematics during gait and squat in the normal knee, specifically focusing on the tibiofemoral axial rotation and contact location of the articular surface.

Methods: Ten subjects without a history of injury in the lower extremity were enrolled in this IRB approved study. There are 5 females and 5 males, the average age was 26.9 years.

Lateral fluoroscopic images of the left knee during gait and squat were recorded. For gait, subjects walked on a treadmill at 1m/sec, and images of the whole gait cycle from heel strike to the next heel strike were recorded at 60 frames/sec. For squat, activity from full extension to maximal flexion was performed in 2 seconds, and was recorded at 10 frames/sec. Subjects also underwent CT scanning with a 1.0mm slice pitch spanning 150mm above and below the knee joint line. Three-dimensional bone models of